

## CLAIMS

- 1 1. An error correction code encoder for encoding data in accordance with one or more  
2 factors of a generator polynomial  $g(x) = g_1(x) * g_2(x)$ , the encoder including:
  - 3 A. a first stage for selectively multiplying symbols by  $g_1(x)$  to produce a product  
4 or dividing the symbols by  $g_1(x)$  to produce one or both of a quotient  $q_1(x)$   
5 and a remainder  $r_1(x)$ ;
  - 6 B. a second stage for dividing  $q_1(x)$  by the polynomial  $g_2(x)$  to produce a  
7 remainder  $r_2(x)$ ;
  - 8 C. a controller for operating the first and second stages, the controller operating
    - 9 a. in a first mode to supply the data to the first stage, the associated  
10 quotient  $q_1(x)$  to the second stage, the associated remainder  $r_2(x)$   
11 produced by the second stage back to the first stage and control the  
12 first stage to produce the product  $r_2(x) * g_1(x)$ ;
    - 13 b. in a second mode to by-pass the second stage; and
    - 14 c. in a third mode to pass the data to the second stage as the quotient  
15  $q_1(x)$ ; and
  - 16 D. a processor for producing ECC symbols by manipulating the remainders and  
17 products produced by the first and second stages.
- 1 2. The encoder of claim 1 wherein the controller operating in the third mode passes the  
2 data through the first stage to supply the data to the second stage as the quotient  $q_1(x)$ .
- 1 3. The encoder of claim 1 wherein the second stage includes  
2  $j$  stages that multiply the symbols by coefficients of degree-one factors of  $g_2(x)$ ;  
3 and  
4 a multiplexer that selectively operates a stage  $j-i$  as the last stage, where  $0 \leq i < j$ .
- 1 4. The encoder of claim 1 wherein the second stage encodes in accordance with  $g_2(x) =$   
2  $g_3(x) * g_4(x)$ , the second stage including:

3 a first sub-stage for selectively multiplying symbols by  $g_3(x)$  to produce a product  
4 or dividing the symbols by  $g_3(x)$  to produce one or both of a quotient  $q_3(x)$  and a  
5 remainder  $r_3(x)$ ;  
6 E. a second sub-stage for dividing  $q_3(x)$  by the polynomial  $g_4(x)$  to produce a  
7 remainder  $r_4(x)$ ;  
8 F. a controller for operating the first and second sub-stages, the controller  
9 operating  
10 in a first mode to supply the quotient  $q_1(x)$  to the first sub-stage, the  
11 associated quotient  $q_3(x)$  to the second stage, the associated remainder  
12  $r_4(x)$  produced by the second sub-stage back to the first sub-stage and  
13 control the first sub-stage to produce the product  $r_4(x)*g_3(x)$ ;  
14 in a second mode to by-pass the second sub-stage; and  
15 in a third mode to pass the quotient  $q_1(x)$  to the second sub-stage as the  
16 quotient  $q_3(x)$ ;  
17 wherein the second stage provides to the processor the remainders and products  
18 produced by the first and second sub-stages.

1 5. An error correction code encoder for encoding data in accordance with one or more  
2 factors of a generator polynomial  $g(x) = g_1(x)*g_2(x)$ , the encoder including:  
3 A. a first stage for selectively multiplying the symbols by  $g_1(x)$  to produce a  
4 product or dividing symbols by  $g_1(x)$  to produce one or both of a quotient  
5  $q_1(x)$  and a remainder  $r_1(x)$ ;  
6 B. a second stage for dividing  $q_1(x)$  by one or more factors of the polynomial  
7  $g_2(x)$  to produce a remainder  $r_2(x)$ ;  
8 C. a controller for operating the first and second stages, the controller operating  
9 a. in a first mode to supply the data to the first stage, the associated  
10 quotient  $q_1(x)$  to the second stage, the associated remainder  $r_2(x)$   
11 produced by the second stage back to the first stage and control the  
12 first stage to produce the product  $r_2(x)*g_1(x)$ ;  
13 b. in a second mode to by-pass the second stage; and

- 14 c. in a third mode to pass the data to the second stage as the quotient  
15  $q_1(x)$ ; and  
16 D. a processor for producing ECC symbols by manipulating the remainders and  
17 products produced by the first and second stages.

1 6. The encoder of claim 4 wherein the second stage includes  
2 j stages that multiply the symbols by coefficients of degree-one factors of  $g_2(x)$ ;  
3 and  
4 a multiplexer that selectively operates a stage j-i as the last stage, where  $0 \leq i < j$ .

1 7. A method for encoding k data symbols in accordance with one or more factors of a  
2 generator polynomial  $g(x) = g_1(x) * g_2(x) * \dots * g_t(x)$  of degree n-k, the method including:  
3 A. using one or more factors of  $g(x)$  as a selected polynomial  $p(x)$  of degree m,  
4 where  $1 \leq m \leq n-k$ ;  
5 B. dividing the data symbols by a first factor  $p_1(x)$  of  $p(x)$  to produce a remainder  
6  $r_1(x)$  and/or a quotient  $q_1(x)$ , the first factor having degree s;  
7 C. if  $p(x)$  has more factors dividing the quotient  $q_1(x)$  by a next factor  $p_i(x)$  of the  
8 polynomial  $p(x)$  to produce a remainder  $r_i(x)$ ;  
9 D. if  $p(x)$  has more factors dividing the quotient  $q_i(x)$  by a next factor  $p_{i+1}(x)$  to  
10 produce a remainder  $r_{i+1}(x)$  and/or a quotient  $q_{i+1}(x)$ ;  
11 E. repeating steps C and D for the remaining factors of  $p(x)$ ; and  
12 F. manipulating the remainders to produce redundancy symbols.

1 8. The method of claim 7 wherein the step of manipulating the remainders includes the  
2 steps of  
3 multiplying the respective remainders  $r_i$  by associated factors  $p_t(x)$ , for  $t =$   
4  $1, 2, \dots, i-1$ ;  
5 adding the results to  $r_1(x)$  to produce a remainder sum; and  
6 shifting the remainder sum by  $x^{n-s}$  to produce ECC symbols.

- 1 9. A method for encoding  $k$  data symbols in accordance with one or more factors of a  
2 generator polynomial  $g(x) = g_1(x) * g_2(x)$  of degree  $n-k$ , the method including:  
3 A. selecting  $g_1(x)$ ,  $g_2(x)$  or  $g_1(x) * g_2(x)$  as a polynomial  $p(x)$  of degree  $m$ , where 1  
4  $\leq m \leq n-k$ ;  
5 B. dividing the data symbols by a first factor  $p_1(x)$  of  $p(x)$  to produce a remainder  
6  $r_1(x)$  and/or a quotient  $q_1(x)$ , the first factor having degree  $s$ ;  
7 C. if  $p(x)$  has a second factor dividing the quotient  $q_1(x)$  by a next factor  $p_2(x)$  of  
8 the polynomial  $p(x)$  to produce a remainder  $r_2(x)$ ; and  
9 D. manipulating the remainders to produce redundancy symbols.

- 1 10. The method of claim 9 wherein the step of manipulating the remainders includes  
2 using  $r_1(x)$  as the ECC symbols.

- 1 11. The method of claim 10 wherein the step of manipulating the remainders includes the  
2 steps of  
3 multiplying  $r_2(x)$  by  $p_1(x)$  to produce a product,  
4 adding the product to  $r_1(x)$  and  
5 shifting the result by  $x^{n-s}$ .

- 1 12. A decoder for decoding a code word that is encoded in accordance with one or more  
2 factors of a generator polynomial  $g(x) = g_1(x) * g_2(x)$ , the decoder including:  
3 A. a first stage for selectively multiplying the symbols by  $g_1(x)$  or dividing  
4 symbols by  $g_1(x)$  to produce either a remainder  $r_1(x)$ , a quotient  $q_1(x)$  or both  
5 the remainder and the quotient;  
6 B. a second stage for dividing the quotient  $q_1(x)$  by the polynomial  $g_2(x)$  to  
7 produce a remainder  $r_2(x)$ ;  
8 C. a controller for operating the first and second stages, the controller operating  
9 a. in a first mode to supply the data to the first stage, the associated  
10 quotient  $q_1(x)$  to the second stage, the associated remainder  $r_2(x)$   
11 produced by the second stage back to the first stage and control the  
12 first stage to produce the product  $r_2(x) * g_1(x)$ ;

- 13                   b. in a second mode to by-pass the second stage; and  
14                   c. in a third mode to pass the data to the second stage as the quotient  
15                    $q_1(x)$ ; and  
16       D. a processor for producing ECC symbols by manipulating the remainders and  
17           products produced by the first and second stages, the processor comparing the  
18           ECC symbols with the code word ECC symbols and, as necessary, producing  
19           error syndromes and correcting errors in the data to produce error-free data.

1   13. A decoder for decoding code words encoded in accordance with one or more factors  
2   of a generator polynomial  $g(x) = g_1(x) * g_2(x)$ , the decoder including:

- 3           A. a first stage for selectively dividing symbols by  $g_1(x)$  to produce a quotient  
4            $q_1(x)$  and/or a remainder  $r_1(x)$  or multiplying the symbols by  $g_1(x)$  to produce  
5           a product;  
6           B. a second stage for dividing  $q_1(x)$  by one or more factors of the polynomial  
7            $g_2(x)$  to produce a remainder  $r_2(x)$  or producing error syndromes associated  
8           with the one or more factors of  $g_2(x)$ ;  
9           C. a controller for operating the first and second stages, the controller operating  
10           a. in a first mode to supply the data to the first stage, the associated  
11           quotient  $q_1(x)$  to the second stage, the associated remainder  $r_2(x)$   
12           produced by the second stage back to the first stage and control the  
13           first stage to produce the product  $r_2(x) * g_1(x)$ ;  
14           b. in a second mode to by-pass the second stage; and  
15           c. in a third mode to pass the data to the second stage as the quotient  
16            $q_1(x)$ ; and  
17           d. in a fourth mode to operate the second stage to produce error  
18           syndromes associated with the one or more factors of  $g_2(x)$ ; and  
19       D. a first processor that produces ECC symbols by manipulating the remainders  
20           and products produced by the first and second stages; and  
21       E. a second processor that produces error syndromes associated with  $g_1(x)$  and  
22           uses the error syndromes produced by the second stage to, as necessary,  
23           correct errors in the data and produce error-free data.